

APPLICATION NOTE FOR PA.710.A ANTENNA INTEGRATION



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1. BASICS

The PA.710.A is a Monopole-PIFA SMD antenna. Knowledge and design of the best environment to use such an antenna is crucial to optimizing its performance and thus the RF device performance itself.

The PA.710.A Planar Inverted F Antenna (PIFA) is without a ground plane under the antenna structure, with rectangular planar elements located in a ceramic substrate, with a short circuiting plate and a feeding mechanism. The product is Surface Mount (SMD) and delivered in tape and reel, making a unique high performance and practical solution for current market needs.

The PA.710.A PIFA antenna couples to the ground to achieve high radiation performance. The size of the ground plane plays an important role in the antenna efficiency and is related to the wavelength, being more effective at low frequencies. The optimal size for a ground plane is 107 x 45 mm, as the evaluation board dimensions. However the antenna can be used for smaller ground-planes with very good results compared to any other existing antenna technology.

This design application note is intended for the antenna integrator to understand the relevant parameters affecting the antenna performance. Taoglas recommends that the integrator strictly follows the guidelines in this application note. Upon your device prototype completion, Taoglas offers further optimization by custom tuning and testing service of the antenna in your device, and assists you in the design process, not just from the antenna perspective but also in achieving an ideal electromagnetic environment.

2. APPLICATIONS

The PA.710.A is an extension version of PA.25A that works from 700MHz to cover LTE bands. It is suitable for all remote side cellular applications, such as GSM, AMPS, GPRS, CDMA, WCDMA, UMTS, HSPA and LTE etc.

This antenna is SMD mounted and a section on the shorter edge of the device's main board needs to be free of metal for the PA.710.A to radiate well.

3. IMPEDANCE

RF circuits in mobile devices should be designed for 50 Ohm impedance at the source (RF module), transmission line (PCB trace or co-axial cable), and load (antenna). In practice, the characteristic impedance of the circuit is never exactly 50 Ohms at different transmitting and receiving bands. The antenna impedance needs to be adjusted to match the actual characteristic impedance of the circuit. For a cellular antenna this is most effective when tuning the antenna at the over the air (OTA) active testing stage in a 3D radiation chamber with the device turned on and using the TRP and TIS numbers as guide to find the best impedance match for the antenna.

4. BANDWIDTH

We normally target a minimum of -5dB return loss at the band edge and -10dB peak for LTE antenna in small mobile device. The ground plane size and antenna surrounding /clearance define the return loss of PA.710.A.

We have designed the PA.710.A on a target board with 107mm long ground plane and 13mm metal-free part to meet the bandwidth requirement for LTE. PA.710.A works well for a PCB with ground length of over 70mm. We also recommend a minimum clearance from metal parts, including PCB ground, of 20mm. Antenna performance would be degraded if the clearance is less than the recommended 20mm.

5. GAIN

The gain of the antenna is closely linked to the effective surface area or volume of the antenna. The larger the surface area or volume of the antenna, the higher the gain that can be obtained. The ideal target for gain for a cellular band antenna in a mobile device, which needs omni-directional radiation characteristics, is a peak gain of 0 dBi. Higher gain means the radiation is higher in certain directions and other directions are reduced. The use of ceramic materials can achieve high efficiencies in small form factors.

6. POLARIZATION

Polarization describes the orientation of the wave oscillation. All Taoglas cellular and broadband antennas are linearly polarized to most efficiently match the signals broadcast from the antennas mounted on cellular base-stations.

Whether it is horizontally or vertically polarized depends on how it is mounted from your frame of reference. The polarization of PA.710.A is along the longer side of the antenna. In practice, the radiation emitted and received by internal antennas would have certain cross-polarization due to reflections from the environment and scattering in the atmosphere.

7. EFFICIENCY

Efficiency is defined as the percentage of the power radiated out from the antenna for a given input. Since mobile or portable devices ideally need to have isotropic radiation with 0 gain, efficiency is a good indication of antenna radiation performance.

In general, 20% efficiency or higher at all bands is good enough for worldwide mobile use. However it is recommended to aim for 40%+ in efficiency if the device needs to pass operator approvals after PTCRB in the US, especially where AT&T approval is required. In this case a ground-plane length of 70mm or above should be used where possible. Shorter ground-plane lengths may still pass approvals but with less certainty. Higher efficiency also translates into better device performance in weak signal areas and lower battery consumption.

Efficiency of the antenna directly relates to the TRP/TIS results of a device in OTA testing if the module has 50 Ohm impedance. However this is only one factor and care must be taken to not single out antenna efficiency as the only reason why a device does not meet certain TRP/TIS targets. Impedance mismatches, conducted power from the module, and noise can sometimes have a greater effect on TRP/TIS than the antenna efficiency.

8. GROUND PLANE EFFECTS

In general for a PIFA, the required PCB ground plane length should be at least one quarter ($\lambda/4$) wavelength of the lowest operating band.

If the ground plane is much smaller than $\lambda/4$ of the lower bands, this will affect the efficiency of the antenna. This will result in having problems radiating the energy.

If the ground plane is much longer than $\lambda/4$ of the lower bands, this will affect the higher frequencies. This is easily observed in the efficiency graph provided for different ground plane lengths in Figure 1.

For those devices where the length of the ground plane is larger than the optimal (107mm), this can be compensated by increasing the width of the ground plane. There is no specific proportion to do this, but we can study case by case depending on your board size.

For those devices where the length of the board is less than 70 mm, there is little to do to improve the antenna performance.

The PIFA antenna must be strictly allocated to one of the shorter sides of the your board. The electromagnetic waves travel parallel to the longest side of the board, increasing radiation of energy. Not following this recommendation will degrade the antenna performance drastically. A larger ground-plane improves return loss and efficiency, but having the max-optimal length at 107 mm (without area for the antenna), when the width is 45 mm and a minimal recommended of 70 mm is required for high efficiency applications.

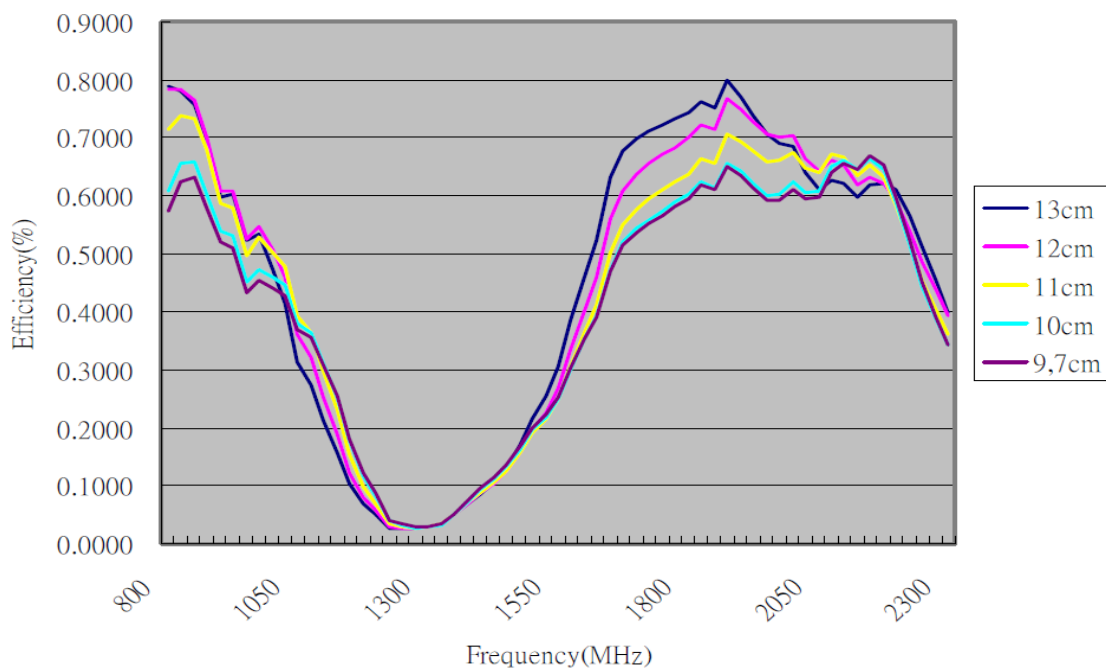


Figure 1. Efficiency at different ground plane lengths.

The top PCB layer ground has the dominant effect on antenna performance compared with ground on other PCB layers. It's important that the device PCB is filled with ground as much as possible on the top and bottom layers, having several via holes to interconnect the ground plane in all layers (top, bottom and middle layers). Also it's important for the Co-Planar Waveguide (CPW) transmission line discussed later.

Components can be allocated on the top and bottom layers of the main board as needed, but any remaining areas must be filled with ground plane. For those places where the ground plane cannot be continued, insert via holes to interconnect with the middle layer ground plane and/or the ground plane at the bottom layer.

9. ISOLATION

Isolation is a measure of coupling between two different antennas. In general, care should be taken to ensure isolation between all antennas in a device. The easiest and most effective method is to place them as far away from each other as possible.

For example, in a MIMO antenna plan the target is to get more than -10dB isolation between antenna one and antenna two. Greater isolation can be achieved by using different polarizations on the two antennas. For example, antenna one can be positioned horizontally and antenna two vertically. In practice this is difficult for omni-directional internal cellular antennas as there is cross-polarization of the waves occurring. So the normal solution is to keep the distance from both antennas as far away as possible.

Testing is carried out by sending a signal to one antenna and measuring the power of the signal at the other antenna, using the S21 on a network analyzer. There should be a 10dB or greater difference between the transmitted and the received signal. One way to achieve adequate isolation is to move the two antennas farther from each other until reaching target isolation.

10. ELECTROMAGNETIC ENVIRONMENT

Close proximity to components or housing affects the electrical performance of all antennas. When placed on a non-conductive area of the board, there should be clearance of 20mm in all directions from metal components for maximum efficiency. A reduction in the efficiency of the antenna and a shift in tuned frequency will be observed if these clearances are not followed. Proximity effects will also have an adverse effect on the radiation pattern of the antenna. Device housings should never be metal or coated with EMI absorption material. For the PA.710.A we recommend at least 3mm of clearance from the enclosure for best performance. Below 1mm will cause major issues, such as antenna detuning and low radiation efficiency.

11. ADVANTAGES

- Compact volume, minimum footprint - It can be placed into the housing of the mobile device, unlike most whip/rod/helix antennas.

- It can be machine surface mounted directly on the edge of the device main-board.

- Transmission losses are kept to absolute minimum resulting in much improved over the air (OTA) device performance compared to similar efficiency cable and connector antenna solutions.

- Reduction in probability of radiated spurious emissions compared to other antenna technologies are observed when using the PA.710.A and strictly following this application note layout.

- Achieves moderate to high gain in both vertical and horizontal polarization planes. This feature is very useful in certain wireless applications where the antenna orientation is not fixed and the reflections or multipath signals may be present from



any plane. In those cases the important parameter to be considered is the total field strength, which is the vector sum of all signals from the horizontal and vertical polarization planes at any instant in time.

- Labour saving SMT – also ensures higher quality yield rate.

- No antenna tooling cost for customer.

12. DESIGNING THE CPW

The CPW (Co-Planar Waveguide) design is only from the GSM Module to the edge of the ground plane. Beyond the edge of the ground plane to the antenna is not a CPW, this is a special interconnection line. Depending on the thickness and number of layers of the board, the CPW can be adjusted to maintain a 50 Ohms +/- 10% system.

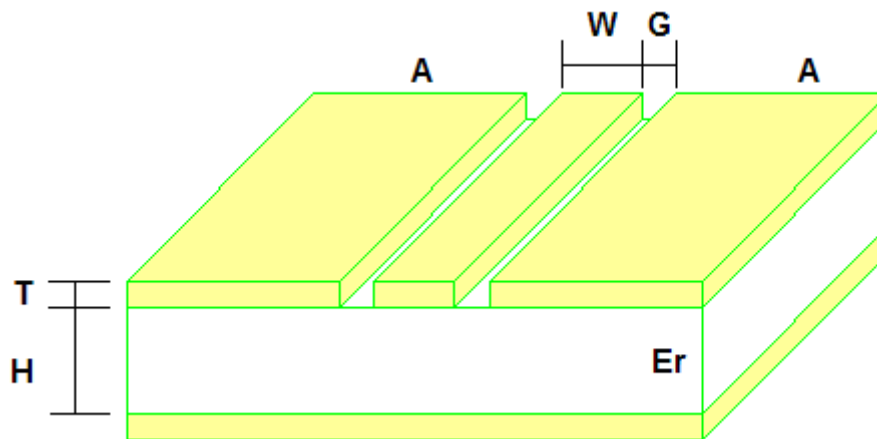


Figure 2. Representation of Co-Planar Waveguide (CPW).

Inputs:

Width=1.2 mm (W)

Gap=0.5 mm (G)

Thickness=0.36 mm (T)

Height=0.76 mm (H)

Dielectric Constant=4.4 (Er)

Conductivity= 5.88×10^7 S/m

Loss Tangent=0.02

Frequency=2170 MHz

Outputs:

Impedance=50.02 Ohms

Loss=1.51 dB/m

The CPW can be adjusted for Gap, Width and Height. For the Gap and Width, Taoglas recommends changing the values but not too far away from those proposed here, so as to avoid abrupt changes in different widths and separations. The CPW can be designed in between the TOP and BOTTOM Layers or in between the TOP and GND Middle Layers.

Depending on the selected pair chosen, the height can be changed to obtain a 50 ohms system depending on each individual project need. In between the pair chosen must be free of other layers, traces, etc, having a cutout where the CPW path is designed.

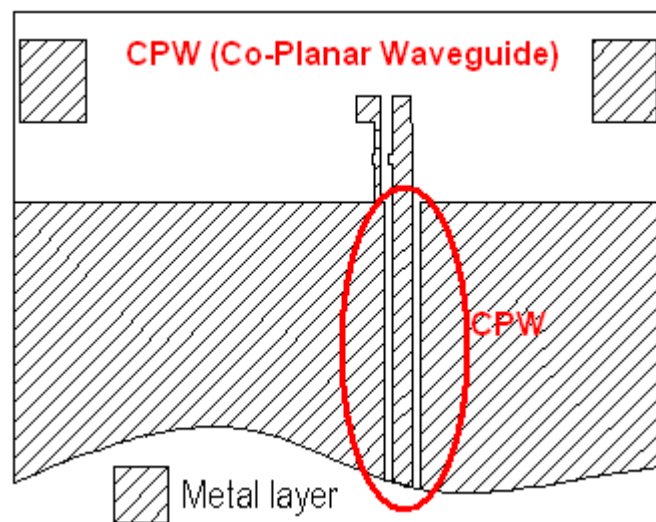


Figure 3. Co-Planar Waveguide (CPW).

We recommend incorporating via holes at the edge of the ground plane aside of the center signal trace from the CPW. This will help to ensure grounds on all layers are well connected to each other and have the same voltage level, thus keeping the 50 ohms system reliable and a proper RF ground plane for the antenna.

Making a fence around the board with via holes will result in a better shielding of the system, providing more resistance against noise issues, better ground, and optimum antenna performance. This via hole fence must interconnect the ground planes in between (TOP, BOTTOM and GND Layers), plus some random via holes on the entire board. The next figure shows via holes around the CPW and fencing the board.

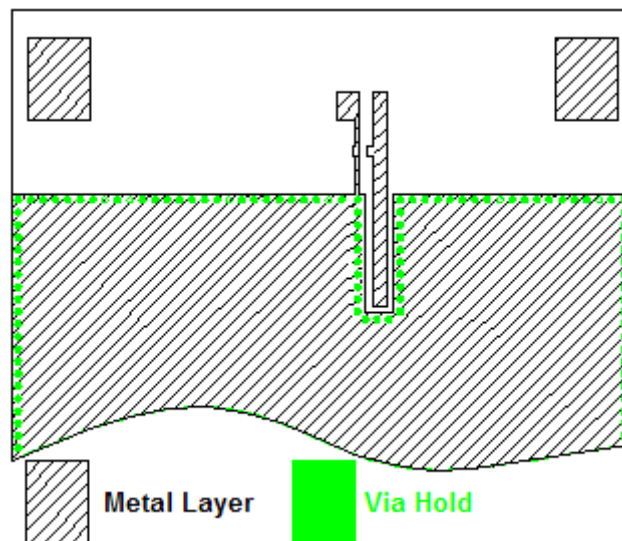


Figure 4. Via holes fence.

13. MATCHING DESIGN

PIFA antennas are less susceptible to detuning from the close environment than other antennas, but adjusting the matching circuit values will usually improve the antenna performance. The PA.710.A needs an 5.6nH (L1 in Figure 5) shunt inductor and a 4.3pF series capacitor (C1 in figure 5) to have 50ohms impedance.

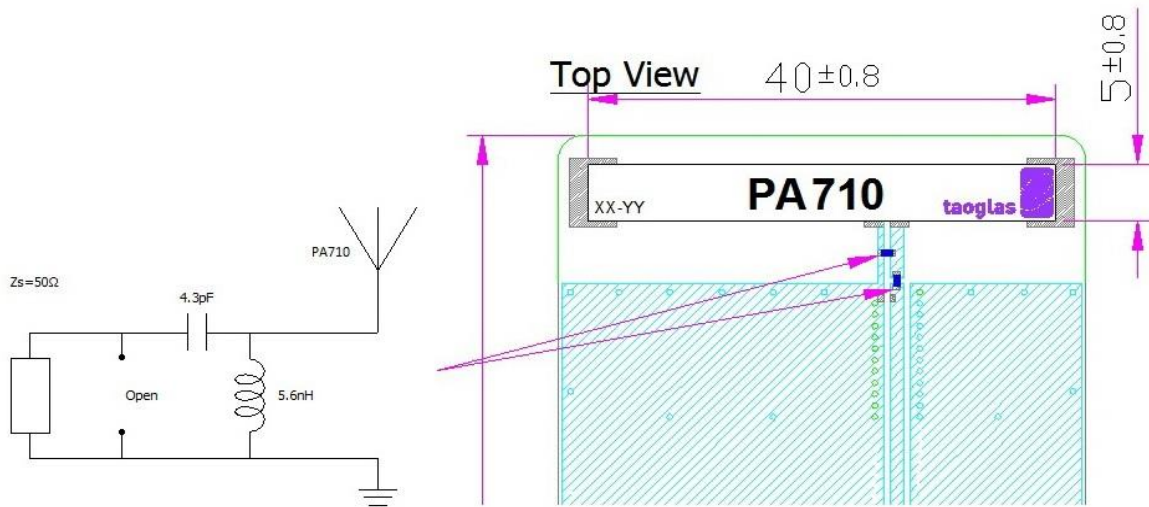


Figure 5. Matching circuit.

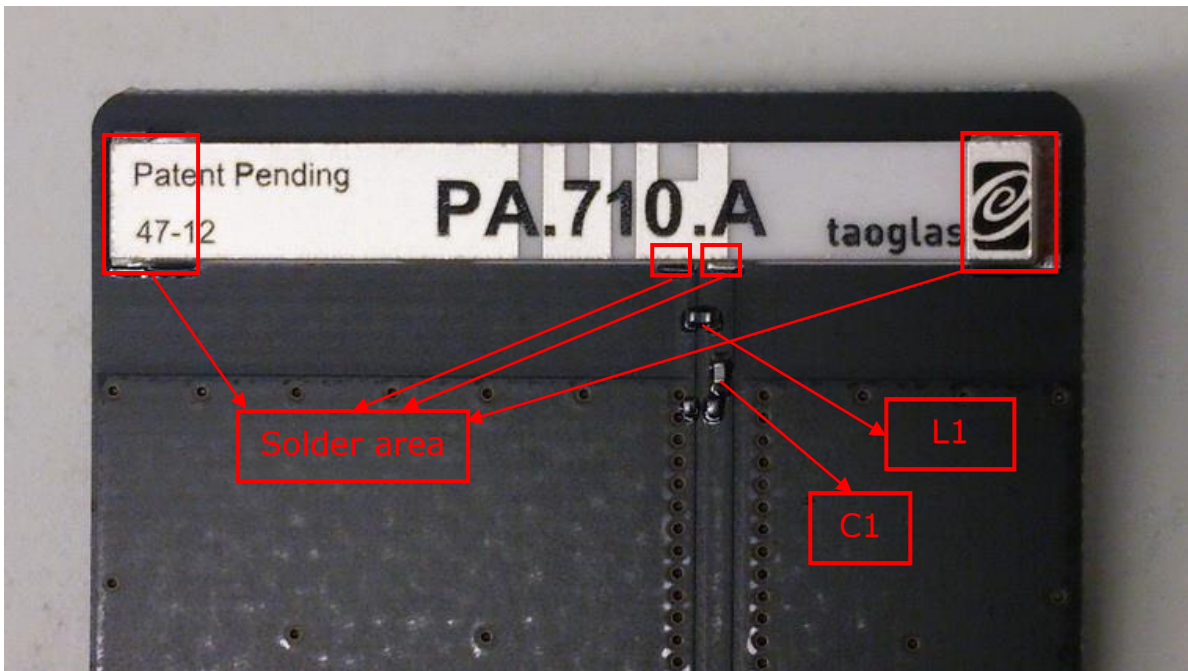


Figure 6. Layout for the Matching circuit.

Circuit Symbol	Size	Description
L1	0402	5.6nH inductor (LQG15HS5N6S02D)
C1	0402	4.3pF Capacitor (GRM1555C1H4R3CA01D)

Mandatory Outside inductor

The PA.710.A needs two lumped components to obtain a 50 Ohm impedance match across the frequency bands. We recommend starting with a 5.6 nH 0402 shunt inductor and a 4.3pF 0402 series capacitor. The exact value of this inductor and capacitor are dependent on the size of the PCB ground plane.

Appropriate choice of matching circuit

Taoglas offers RF integration services. If the customer uses our service they can give the housing and reference PCB to Taoglas. Taoglas can carry out the necessary S11 response measurements in both magnitude and Smith Chart formats of the complete system. The necessary impedance matching circuit should be designed on the customer side if they have access to a software modeling tool which simulates the system.

The matching circuit values obtained from this exercise can then be employed and adjusted via measurement and simulation to obtain the optimal 50 Ohm match at the frequencies of interest, establishing the type and values for the lumped components. It should be noted that impedance matching can improve the response of the antenna at certain frequencies (or bands of frequencies in the case of wideband matching circuits) but a reduction in the response at other frequencies may be observed.

14. MOUNTING

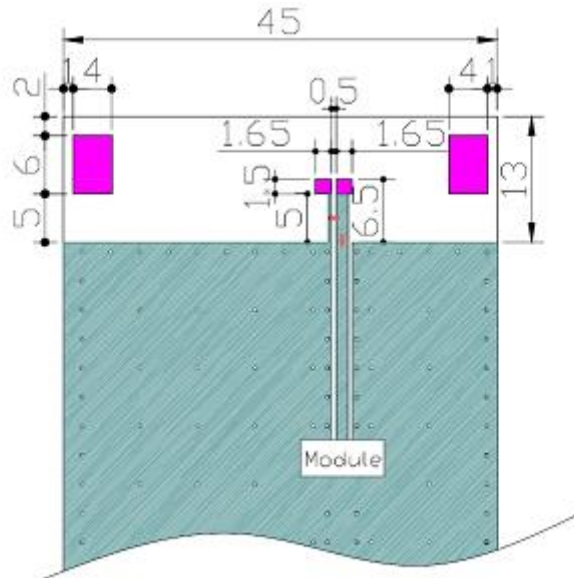


Figure 7. Baseline PCB Layout.

The size of the ground plane for the complete evaluation board is 107x45 mm (maximum performance). The size of the entire board including the antenna area free of ground plane is 120x 45 mm. The area occupied by the antenna is 45x13 mm.

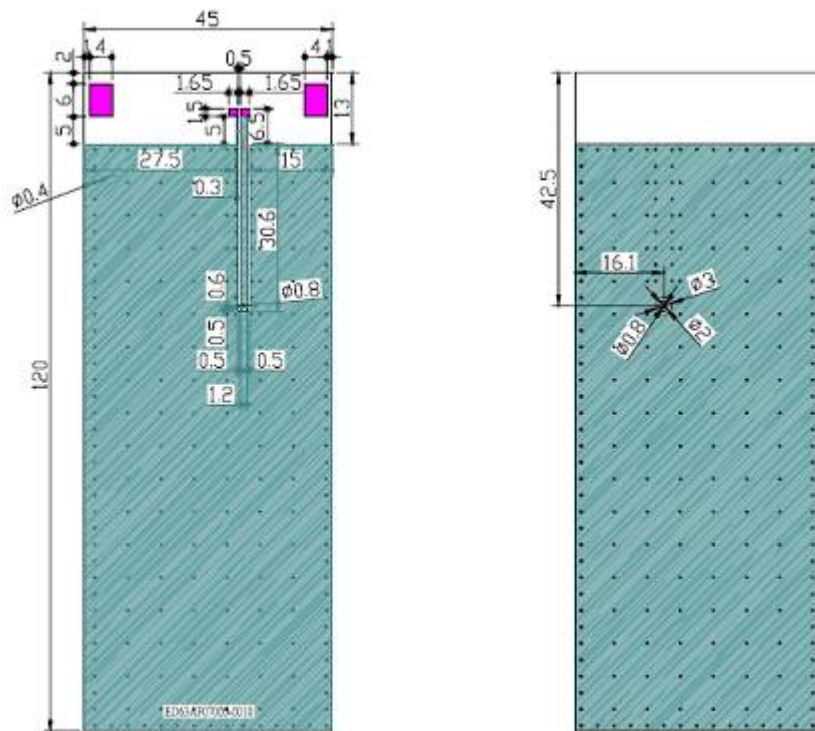


Figure 8. PA.710.A EVB Layout.

15. ***MAJOR RESTRICTIONS***

Under no circumstances must the ground plane be placed beside the antenna, nor components, metal screws, or metal structures even if they are not grounded. These metal structures behave like they are grounded. No metal components or ground plane must be placed beyond the edge of the ground plane, above or below the PCB. The edge of the ground plane must be cut in flat shape along that side, as in the green line in the next figure.

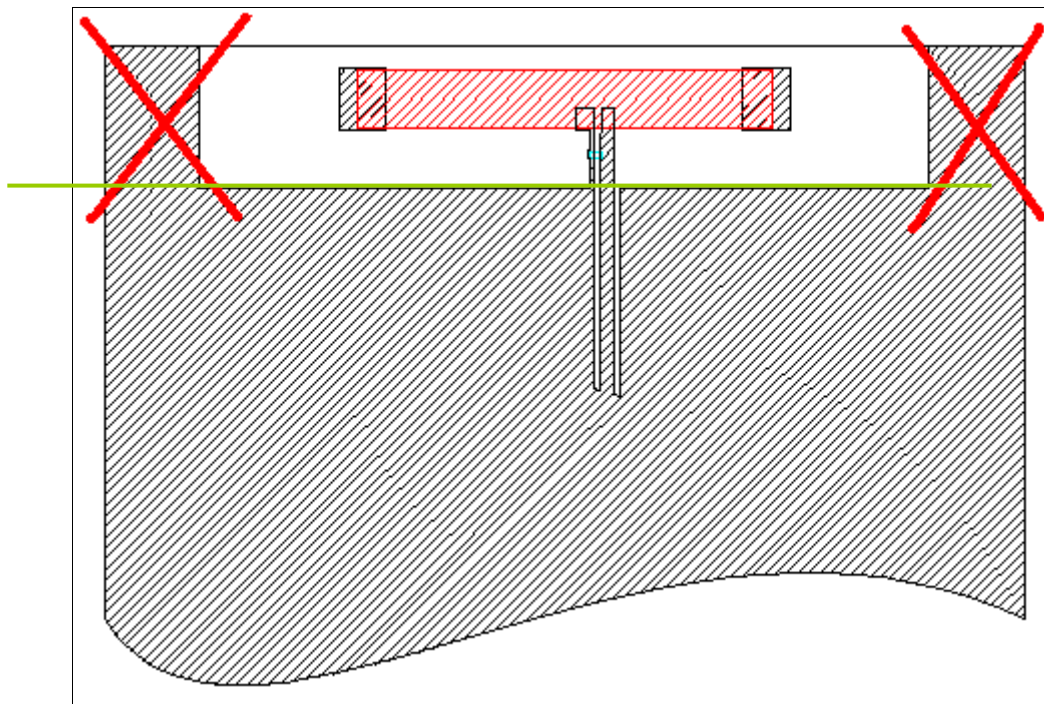


Figure 9. Solder pad and mask areas.

Do not place metal components, ground plane, daughter boards, LCD, or other metal structures near the antenna, on the sides, above, or below on the other side of the board. All these structures must stop at the edge of the ground plane where the green line is drawn in the above figure.

If a thicker component is placed near the end of the ground plane edge, it is better to have a larger clearance of more than 5 mm, such as an LCD panel, high metal components, etc.

We strictly recommend allocating the antenna on one of the shorter sides for rectangular boards.